8. Baseline Ecological Risk Assessment

This chapter presents a summary of the Onondaga Lake Baseline Ecological Risk Assessment (BERA) report (TAMS, 2002a) for the remedial investigation (RI) and feasibility study (FS) for Onondaga Lake. The objective of the BERA is to evaluate the potential for adverse ecological effects associated with current exposures to chemicals and stressors present in Onondaga Lake in the absence of any action to control or mitigate those contaminants (i.e., under the no-action alternative).

For the purposes of the BERA, the Onondaga Lake site includes the following areas:

- The entire lake, including all pelagic and littoral areas.
- The mouths of all tributaries to the lake, including Ley Creek, Onondaga Creek, Harbor Brook, the East Flume, Tributary 5A, Ninemile Creek, Sawmill Creek, and Bloody Brook.
- The area from the lake outlet to the water sampling location in the outlet (Station W12), approximately 200 m downstream of the lake near the New York State Thruway bridge.
- Two of the New York State-regulated wetlands contiguous to the lake (Wetlands SYW-6 and SYW-12).

In addition to the areas of the site listed above, the BERA includes an evaluation of limited data that were collected in Wetlands SYW-10 and SYW-19 and an upland area associated with the dredge spoils area located north of the mouth of Ninemile Creek. Ecological risks associated with Wetlands SYW-10 and SYW-19 and the dredge spoils area will be further evaluated as part of separate sites and, therefore, the risk analysis associated with these areas in the BERA is considered preliminary, pending the finalization of the BERAs associated with these other sites. Specifically, Wetland SYW-10 will be further evaluated as part of the RI/FS for the Geddes Brook/Ninemile Creek site; Wetland SYW-19 will be further evaluated as part of the RI/FS for the Wastebed B/Harbor Brook site; and the dredge spoils area will be further evaluated as a separate site with its own investigation.

In addition to the investigations performed at the above-listed areas, ongoing or completed investigations conducted separately by Honeywell, the New York State Department of Environmental Conservation (NYSDEC), and others at hazardous waste sites and areas of concern near Onondaga Lake are discussed in the BERA.

The BERA was structured to follow the Superfund risk assessment process and consists of the following sections:

- Chapter 1, Introduction – Discusses the general framework and format of the document.

- Chapter 2, Summary of Honeywell and Other Industrial Facilities and Environmental Investigations – Describes Honeywell facilities and related areas near Onondaga Lake and environmental studies conducted at those facilities.

- Chapter 3, Site Description (FWIA Step I) – Presents information about fish and wildlife resources near Onondaga Lake.

- Chapter 4, Screening-Level Problem Formulation and Ecological Effects Evaluation (ERAGS Step 1) – Presents the initial screening-level steps of the ecological risk assessment in which preliminary chemicals of potential concern/stressors of potential concern (COPCs/SOPCs) and ecological receptors are identified and a preliminary site conceptual model is developed.

- Chapter 5, Screening-Level Exposure Estimate and Risk Calculation (ERAGS Step 2) – Presents the results of screening-level risk calculations used to refine the list of preliminary COPCs/SOPCs that should be carried forward in the risk assessment.

- Chapter 6, Baseline Risk Assessment Problem Formulation (ERAGS Step 3) – Presents the baseline risk assessment problem formulation; refines preliminary chemicals of concern/stressors of concern (COCs/SOCs); characterizes ecological effects of contaminants; reviews information on contaminant fate and transport, complete exposure pathways, and ecosystems potentially at risk; selects assessment endpoints; and develops a conceptual model.

- Chapter 7, Study Design (ERAGS Steps 4 and 5) – Develops measurement endpoints and describes the study design by summarizing major components of the Onondaga Lake work plan and sampling and analysis plan.

- Chapter 8, Analysis of Ecological Exposures (ERAGS Step 6) – Presents information on exposure characterization.

- Chapter 9, Analysis of Ecological Effects (ERAGS Step 6) – Presents information on effects characterization.

- Chapter 10, Risk Characterization (ERAGS Step 7) – Integrates information on exposure and effects to estimate potential risks.

- Chapter 11, Uncertainty Analysis (ERAGS Step 7) – Evaluates various sources of uncertainty in the risk assessment.

- Chapter 12, Conclusions – Summarizes the major findings of the ecological risk assessment.

- Chapter 13, References – Presents references for all documents, Internet sites, and personal communications cited in the main body of the report.

- Appendix A – Characteristics of Covertypes in the Onondaga Lake Area.

- Appendix B – Water Quality Data.

- Appendix C – New York Natural Heritage Program and US Fish and Wildlife Service Letters.

- Appendix D – Screening-Level Risk Tables.

- Appendix E – Exceedances of NYSDEC Sediment Quality Values.

- Appendix F – Exceedances of Onondaga Lake Sediment Effect Concentrations and Probable Effect Concentrations.

- Appendix G – Review of Honeywell Sites and Other Potential Source Areas.

- Appendix H – Exposure Concentration and Food-Web Model Calculations.

- Appendix I – Summary of Data Used in the BERA.

The implementation of the BERA follows the Superfund risk assessment process specified by the US Environmental Protection Agency (USEPA) (1997b) to evaluate the likelihood that adverse ecological effects are occurring or may occur as a result of exposure to one or more contaminants or stressors (see text box below). The specifications of NYSDEC (1994), particularly those specifications that are not identified by USEPA (1997b, 1998), have been incorporated into the BERA, so that the relevant New York State guidance was accommodated within the structure recommended by USEPA.

The first seven steps of the Superfund ecological risk assessment process were completed from 1990 through the present, inclusive of this report, and the final step will be determined by the NYSDEC and USEPA, with the assistance of the New York State Department of Health (NYSDOH) and the New York State Department of Law (NYSDOL), during the feasibility study (FS) and Record of Decision (ROD) process.

The Eight Steps of the Superfund Ecological Risk Assessment Process

1.) Screening-level problem formulation and ecological effects evaluation.

2.) Screening-level preliminary exposure estimate and risk calculation.

3.) Baseline risk assessment problem formulation.

4.) Study design and data quality objectives.

5.) Field verification of sampling design.

6.) Site investigation and analysis of exposure and effects.

7.) Risk characterization.

8.) Risk management.

8.1 Site History and Description

Chapters 2 and 3 of the BERA summarize the physical attributes of the sites, the history of contamination, and the regulatory history. This information is presented in greater detail in Chapters 1 through 4 of this RI.

8.2 Screening-Level Problem Formulation and Screening

Initial screening-level problem formulation for Onondaga Lake was largely completed during preparation of Honeywell's Onondaga Lake RI/FS Work Plan (PTI, 1991c). As part of the work plan, a conceptual site model was developed, preliminary COPCs/SOPCs and representative ecological receptors were identified, assessment and measurement endpoints were defined, the objectives of the BERA were formulated, and a study design was developed to collect the data needed to satisfy the BERA objectives. Although initial problem formulation for the work plan was largely completed in 1991, several elements of the screening-level problem formulation have been refined since that time, based on information collected during the 1992 and 1999/2000 RI field investigations, or by using information collected by other parties, such as NYSDEC. The RI field investigations conducted by Honeywell in 1992 and 1999/2000 and by NYSDEC in 2002 cover the site investigation portions of Steps 4 to 6 of the USEPA Superfund ecological risk assessment process.

The preliminary conceptual site model for the Onondaga Lake BERA, which was retained with minor revisions as the site conceptual model for the BERA, is presented in Figure 8-1. The conceptual site model identifies primary and secondary sources, potential pathways, major contaminants/stressor groups, potential exposure routes and receptors, and effects to be initially evaluated as part of the BERA. Animals and plants are directly exposed to contaminants and stressors primarily from contaminated sediments and lake water and animals are indirectly exposed through ingestion of food (e.g., prey) containing contaminants.

8.3 Contaminants/Stressors of Concern

Numerous potentially toxic chemicals, including mercury, cadmium, chromium, copper, lead, nickel, zinc, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), benzene, toluene, ethylbenzene, xylenes (BTEX), chlorinated benzenes, and dioxins/furans, were detected at elevated concentrations in various lake media. For each complete exposure pathway, route, and chemical, a screening ecotoxicity value was selected to establish contaminant exposure levels that represent conservative thresholds for adverse ecological effects. COCs selected for water, surface sediment, surface soil, plants, fish, and wildlife receptors are presented in Tables 8-1 and 8-2.

Stressors identified in Superfund guidance are referred to as chemical contaminants in the BERA, whereas non-Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) stressors, such as chloride, depleted dissolved oxygen (DO), and reduced water transparency, are referred to as stressors. Only chemicals covered under CERCLA Section 40 CFR Part 302.4, which lists the CERCLA hazardous substances, were included in the COC selection. The exception to this is ammonia, which is listed as a hazardous substance in the CFR, but is treated as an SOC in the BERA since it is associated with discharges from the Metropolitan Syracuse Sewage Treatment Plant (Metro), as well as various Honeywell sites, and is a nutrient. The major groups of stressors in Onondaga Lake, including nutrients (i.e., nitrite, phosphorus, sulfide), calcite, salinity, ammonia, depleted DO, and reduced water transparency, were retained for further examination in the BERA.

8.4 Assessment Endpoints

Assessment endpoints are explicit expressions of the actual environmental values that are to be protected and focus a risk assessment on particular components of the ecosystem that could be adversely affected due to contaminants and stressors at the site. Assessment endpoints are often expressed in terms of populations or communities. Because mercury and some of the other COCs, such as PCBs and polychlorinated dibenzo-*p*-dioxins and polychlorinated dibenzofurans (PCDD/PCDFs), at Onondaga Lake are known to bioaccumulate, an emphasis was also placed on indirect exposure at various levels of the food chain to address COC-related risks at higher trophic levels. In addition, assessment endpoints were also selected for communities that may have been affected by stressors. The 13 assessment endpoints that were selected for Onondaga Lake are:

- Sustainability (i.e., survival, growth, and reproduction) of an aquatic macrophyte community that can serve as a shelter and food source for local invertebrates, fish, and wildlife.

- Sustainability (i.e., survival, growth, and reproduction) of a phytoplankton community that can serve as a food source for local invertebrates, fish, and wildlife.

- Sustainability (i.e., survival, growth, and reproduction) of a zooplankton community that can serve as a food source for local invertebrates, fish, and wildlife.

- Sustainability (i.e., survival, growth, and reproduction) of a terrestrial plant community that can serve as a shelter and food source for local invertebrates and wildlife.

- Sustainability (i.e., survival, growth, and reproduction) of a benthic invertebrate community that can serve as a food source for local fish and wildlife.

- Sustainability (i.e., survival, growth, and reproduction) of local fish populations.

- Sustainability (i.e., survival, growth, and reproduction) of local amphibian and reptile populations.

- Sustainability (i.e., survival, growth, and reproduction) of local insectivorous bird populations.

- Sustainability (i.e., survival, growth, and reproduction) of local benthivorous waterfowl populations.

- Sustainability (i.e., survival, growth, and reproduction) of local piscivorous bird populations.

- Sustainability (i.e., survival, growth, and reproduction) of local carnivorous bird populations.

- Sustainability (i.e., survival, growth, and reproduction) of local insectivorous (aquatic and terrestrial insect phases) mammal populations.

- Sustainability (i.e., survival, growth, and reproduction) of local piscivorous mammal populations.

8.5 Measurement Endpoints

Measurement endpoints provide the actual values used to evaluate each assessment endpoint. Measurement endpoints generally include measured or modeled concentrations of chemicals and stressors in water, sediment, fish, birds, and/or mammals, laboratory toxicity studies, and field observations. Measurement endpoints in relation to their respective assessment endpoints were phrased in relation to respective risk questions contained in the BERA. Each assessment endpoint in the BERA had a minimum of two measurement endpoints that were used as lines of evidence. Measurement endpoints identified for the Onondaga Lake BERA include:

- Community structure (aquatic macrophytes, phytoplankton, zooplankton, fish) as compared to reference communities.

- Laboratory (greenhouse studies) and field experiments measuring macrophyte growth and survival.

- Laboratory toxicity studies measuring macroinvertebrate, growth, survival, and reproduction.

- Benthic community indices, such as richness, abundance, diversity, and biomass.

- Observed effects on fish foraging and nesting.

- Observed fish abnormalities.

- Measured total COC body burdens in fish to determine exceedance of effect-level thresholds based on toxicity reference values (TRVs).

- Laboratory toxicity studies examining effects of lake water on amphibian embryos.

- Modeled total COC body burdens in wildlife receptors to determine exceedance of effect-level thresholds based on TRVs.

- Exceedance of criteria for concentrations of COCs/SOCs in lake water that are protective of aquatic organisms, fish, and wildlife.

- Exceedance of guidelines for concentrations of COCs/SOCs in sediments that are protective of aquatic health.

- Exceedance of guidelines for concentrations of COCs/SOCs in soils that are protective of plant health.

- Field observations.

8.6 Ecological Receptors

The risks to the environment were evaluated for receptors that were selected to be representative of various communities, feeding preferences, predatory levels, and aquatic and wetland habitats. Individual assessment endpoints were evaluated with a minimum of one "model" (receptor) species. The following receptors were selected for the Onondaga Lake BERA:

- Aquatic macrophyte community.

- Phytoplankton community.

- Zooplankton community.

- Terrestrial plant community.

- Benthic invertebrate community.

- Fish: bluegill (*Lepomis macrochirus*); carp (*Cyprinus carpio*); channel catfish (*Ictalurus punctatus*); gizzard shad (*Dorosoma cepedianum*); largemouth bass (*Micropterus salmoides*); smallmouth bass (*Micropterus dolomieui*); walleye (*Stizostedion vitreum*); and white perch (*Morone americana*).

- Amphibian and reptile communities.

- Insectivorous birds: tree swallow (*Tachycineta bicolor*).

- Benthivorous waterfowl: mallard (*Anas platyrhynchos*).

- Piscivorous birds: belted kingfisher (*Ceryle alcyon*); great blue heron (*Ardea herodias*); and osprey (*Pandion haliaetus*).

- Carnivorous birds: red-tailed hawk (*Buteo jamaicensis*).

- Insectivorous mammals: little brown bat (*Myotis lucifugus*) – aquatic invertebrates; short-tailed shrew (*Blarina brevicauda*) – terrestrial invertebrates.

- Piscivorous mammals: mink (*Mustela vison*) and river otter (*Lutra canadensis*).

8.7 Exposure Assessment

The exposure assessment describes complete exposure pathways and exposure parameters. The contaminants and ecological components of the Onondaga Lake ecosystem were temporally and spatially characterized to obtain an exposure profile. The distribution of chemicals and stressors in each medium (i.e., lake water, surface sediments, wetland surface soil, dredge spoil surface soils, plankton, macroinvertebrates, and fish) to which ecological receptors may be exposed was examined and exposure point concentrations (EPCs) were calculated. Biota uptake and food-web exposure models were developed.

Receptor parameters, such as body weight, prey ingestion rate, home range, etc., were used in the food-web models to calculate COC dietary doses for wildlife. Exposure parameters were obtained from USEPA references, the scientific literature, and directly from researchers. The resulting exposure profiles for each receptor quantified the spatial and temporal patterns of exposure as they relate to the assessment endpoints and risk questions.

8.8 Effects Assessment

The effects assessment describes the methods used to characterize effects on aquatic and terrestrial organisms due to exposure to chemicals and stressors. Chemical exposure was evaluated using measures of toxicological effects (e.g., TRVs) that provide a basis for estimating whether the chemical exposure at a site is likely to result in adverse ecological effects. Exposure to stressors was evaluated using available literature, concentrating on studies specific to Onondaga Lake when possible.

For chemical exposure, TRVs were selected based on lowest observed adverse effects levels (LOAELs) and/or no observed adverse effects levels (NOAELs) from laboratory and/or field-based studies reported in the scientific literature. These TRVs examine the effects of COCs on the survival, growth, and reproduction of fish and wildlife species in Onondaga Lake. Reproductive effects (e.g., egg maturation, egg hatchability, and survival of juveniles) were generally the most sensitive exposure endpoints and were selected when available and appropriate.

Site-specific sediment effect concentrations (SECs) using toxicity and chemistry data were derived to allow assessment of whether the sediment chemical concentrations found at various stations in the lake would result in adverse biological effects. Five site-specific SECs were developed for Onondaga Lake using the apparent effects threshold (AET) approach and calculation of effects range-low (ER-L), effects range-median (ER-M), probable effect level (PEL), and threshold effects level (TEL) concentrations. These SECs were then used to derive a consensus-based probable effect concentration (PEC) for use in determining areas of the lake bottom that potentially pose a risk to the benthic community.

8.9 Risk Characterization

Risk characterization integrates the exposure and effects assessments and examines the likelihood of adverse ecological effects occurring as a result of exposure to chemicals and/or stressors. The Onondaga Lake BERA employed a strength-of-evidence approach, using several lines of evidence to evaluate each assessment endpoint.

Toxicological risks were estimated by comparing the results of the exposure assessment (measured or modeled concentrations of chemicals in receptors of concern) to the TRVs developed in the effects assessment, resulting in a ratio of these two numbers, called a hazard quotient (HQ). HQs equal to or greater than 1.0 ($HQ \geq 1$) are typically considered to indicate potential risk to ecological receptors; for example, with reduced or impaired reproduction or recruitment. The HQs provide insight into the potential for adverse effects upon individual animals in the local population resulting from chemical exposure. If an HQ suggests that effects are not expected to occur for the average individual, then they are probably insignificant at the population level. However, if an HQ indicates that risks are present for the average individual, then risks may be present for the local population.

Other measurement endpoints, such as field observations and toxicity studies, were evaluated in conjunction with toxicological risks on a receptor-specific basis. Use of several lines of evidence resulted in the following risk characterizations for each assessment endpoint.

8.9.1 Sustainability (i.e., Survival, Growth, and Reproduction) of an Aquatic Macrophyte Community That Can Serve as a Shelter and Food Source for Local Invertebrates, Fish, and Wildlife

Sustainability of an aquatic macrophyte community that can serve as a shelter and food source for local invertebrates, fish, and wildlife was assessed using three lines of evidence. The first was comparison of the Onondaga Lake macrophyte community to reference location communities. The second was to evaluate growth and survival of macrophytes in Onondaga Lake using field and laboratory studies. The third was a qualitative evaluation of lake conditions relative to NYSDEC narrative water quality standards (6 NYCRR Part 703.2). All three measurement endpoints indicate that the macrophyte community of Onondaga Lake has been adversely affected by the input of chemicals and stressors into the lake. These impacts may affect animals that use the macrophytes in Onondaga Lake for food and shelter.

8.9.2 Sustainability (i.e., Survival, Growth, and Reproduction) of a Phytoplankton Community That Can Serve as a Food Source for Local Invertebrates, Fish, and Wildlife

Sustainability of a phytoplankton community that can serve as a food source for local invertebrates, fish, and wildlife was assessed using two lines of evidence. The first was field observations of the Onondaga Lake phytoplankton community and the second was a qualitative evaluation of NYSDEC narrative water quality standards. Both measurement endpoints indicate that the phytoplankton community has been impacted by chemicals and/or stressors in lake water. Mercury has been shown to bioaccumulate in phytoplankton in Onondaga Lake and may be passed on to higher trophic levels feeding on phytoplankton in Onondaga Lake. Stressors have been shown to influence the abundance and distribution of phytoplankton species.

8.9.3 Sustainability (i.e., Survival, Growth, and Reproduction) of a Zooplankton Community That Can Serve as a Food Source for Local Invertebrates, Fish, and Wildlife

Sustainability of a zooplankton community that can serve as a food source for local invertebrates, fish, and wildlife was assessed using three lines of evidence. The first was field observations of the Onondaga Lake zooplankton community. The second was to compare surface water concentrations to water quality criteria developed for the protection of aquatic life. The third was a comparison of contaminant concentrations in sediment to NYSDEC and/or USEPA sediment guidelines. All three of these lines of evidence indicate that the zooplankton community of Onondaga Lake has been impacted by high levels of chemicals and/or stressors in lake water. In particular, high levels of salinity and mercury appear to have influenced community structure and abundance. Although the zooplankton community has been impacted by lake conditions, it still serves as a food source for local invertebrates, fish, and wildlife, and as such passes bioaccumulative contaminants (e.g., mercury) through the food chain.

8.9.4 Sustainability (i.e., Survival, Growth, and Reproduction) of a Terrestrial Plant Community That Can Serve as a Shelter and Food Source for Local Invertebrates and Wildlife

Sustainability of a terrestrial plant community that can serve as a shelter and food source for local invertebrates and wildlife was assessed using two lines of evidence. The first was field observations of the Onondaga Lake terrestrial plant community. Only obvious effects, such as the sparse vegetation found on the wastebeds, can be directly attributed to activities at Honeywell facilities (i.e., disposal of Solvay and other industrial wastes). The second was to compare surface soil concentrations to plant toxicity values. Comparisons of soil chemical concentrations to plant toxicity values indicate that high levels of contaminants, in particular chromium and mercury, may adversely affect the plant community and subsequently local invertebrates and wildlife that live or forage in local habitats. These results suggest the potential for adverse effects on plants via exposure to COCs in soils at all four wetland areas and the dredge spoils area.

8.9.5 Sustainability (i.e., Survival, Growth, and Reproduction) of a Benthic Invertebrate Community That Can Serve as a Food Source for Local Fish and Wildlife

The potential effect of COCs and SOCs on the benthic community in Onondaga Lake was evaluated using the following four lines of evidence: exceedance of water quality criteria, benthic community metrics analysis, sediment toxicity testing, and sediment chemistry through the derivation of site-specific PECs.

Concentrations of chemicals in Onondaga Lake water were found to exceed surface water criteria in certain areas of the lake. There were more exceedances of surface water criteria in the tributaries to Onondaga Lake than in the lake itself. In addition, stressors in Onondaga Lake, including chloride, salinity, ammonia, nitrite, and phosphorus, generally exceeded guidelines (when available) or background levels. A qualitative evaluation of NYSDEC narrative water quality standards indicated that those standards were also exceeded.

The benthic invertebrate community metrics analyzed in the BERA included: taxa richness, dominance, abundance of indicator species, species diversity, and percent model affinity (PMA). The analysis of these metrics showed that many of the benthic invertebrates communities living in the littoral zone (less than 5 m depth) in Onondaga Lake and the mouths of its tributaries have been impacted to some degree. The majority of moderately and severely impacted stations were located between Tributary 5A and Ley Creek, with the most severely impacted stations located between Tributary 5A and Onondaga Creek.

Short-term (10-day) and long-term (40/42-day) bulk sediment toxicity tests were performed for the BERA using sediments collected from all lake environs. The results of the sediment toxicity tests confirmed that some Onondaga Lake sediments are toxic to benthic invertebrates and may increase mortality and reduce the growth and fecundity of these organisms. The most toxic sediments are found in the nearshore zone in the southern part of the lake between Tributary 5A and Ley Creek.

Five SECs (i.e., calculation of AET, ER-L, ER-M, PEL, and TEL values) were derived to allow site-specific assessment of whether the sediment chemical concentrations found at various Onondaga Lake stations would result in adverse biological effects. These SECs were then used to derive a consensus-based PEC (i.e, the contaminant concentration above which adverse effects are expected to frequently occur) to determine areas of the lake bottom that pose some degree of risk to the benthic community. The PECs were derived as the geometric mean of the five site-specific SECs and are presented in Table 8-3.

Using the consensus PECs, measured surface sediment concentrations exceed the values at many locations throughout Onondaga Lake. Only 14 of approximately 200 locations sampled in 1992 and 2000 do not have at least one compound exceeding an HQ of 1.0 (i.e., sediment concentration less than the PEC). Many of the ratios of measured sediment concentrations to PECs exceed 10, or even 100, between Tributary 5A and Ley Creek. In addition, these sediment locations have the highest number of compounds – between 11 and over 30 compounds per sample – that exceed their PECs in a sample.

Based on the above, all four lines of evidence suggest an adverse effect from COCs and SOCs on the benthic invertebrate populations in Onondaga Lake, particularly in the southern part of the lake from Tributary 5A to Ley Creek. Based on these analyses it can also be concluded that local fish and wildlife populations using the benthic invertebrate community as a food source in turn are impacted.

8.9.6 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Fish Populations

The sustainability of local fish populations was assessed using six lines of evidence. The first was to examine the fish community structure as compared to similar lakes and historic accounts of Onondaga Lake (prior to industrial activities) in relation to the health of local fish populations. The second was to look for potential effects of chemicals/stressors on fish foraging and nesting. The third was to compare visual abnormalities (e.g., tumors, lesions) in Onondaga Lake fish to fish from other lakes. The fourth was to compare measured water column concentrations to water quality criteria for the protection of aquatic life, including NYSDEC narrative standards. The fifth was to compare measured sediment concentrations to guidelines for the protection of aquatic life for benthic-dwelling species of fish. The sixth and final line of evidence was to compare measured concentrations of chemicals in fish representing various feeding strategies and trophic levels to TRVs.

Risks to fish from chemicals were evaluated on a species-specific basis using measured body burdens for eight fish species representing the Onondaga Lake fish community (Table 8-4). A limited number of chemicals (e.g., methylmercury) were analyzed in some species (e.g., gizzard shad and largemouth bass). Therefore, actual risks from chemicals in lake water may be greater for these species than calculated. HQs greater than 1.0 were calculated for the following chemicals (by species):

- Bluegill – arsenic, chromium, endrin, mercury, selenium, vanadium, and zinc.
- Carp – arsenic, chromium, dioxin/furans, endrin, mercury, total PCBs, selenium, vanadium, and zinc.
- Catfish – chromium, endrin, methylmercury, mercury, total PCBs, selenium, vanadium, and zinc.
- Gizzard shad – methylmercury.
- Largemouth bass – methylmercury and dioxins/furans.
- Smallmouth bass – arsenic, chromium, mercury, methylmercury, total PCBs, selenium, vanadium, and zinc.
- Walleye – chromium, mercury, methylmercury, and total PCBs.
- White perch – chromium, mercury, methylmercury, selenium, and total PCBs.

Five of the six lines of evidence evaluated suggest adverse effects from the COCs identified above on the Onondaga Lake fish community and the remaining line of evidence, incidence of visual abnormalities, was inconclusive. This strength-of-evidence approach indicates that local fish populations are adversely affected by the chemicals and stressors present in Onondaga Lake.

8.9.7 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Amphibian and Reptile Populations

Sustainability of local amphibian and reptile populations was assessed using three lines of evidence. The first was to conduct a field survey of local amphibian and reptile populations around Onondaga Lake. The second was to compare measured water column concentrations to water quality criteria for the protection of aquatic life, including NYSDEC narrative standards. The third and final line of evidence was laboratory studies examining the effects of Onondaga Lake water on amphibian embryos. All three lines of evidence strongly indicate that amphibian and reptile populations have been adversely affected by chemicals and/or stressors found in Onondaga Lake water.

8.9.8 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Insectivorous Bird Populations

Sustainability of local insectivorous bird populations was assessed using three lines of evidence. The first was modeling dietary doses of chemicals. The second was to compare measured water column concentrations to water quality criteria for the protection of wildlife. The third line of evidence was field-based observation. The first two lines of evidence suggested that insectivorous birds have been adversely affected to some degree by chemicals found in Onondaga Lake and taken up by the aquatic phases (e.g., egg, larvae) of invertebrates. Mercury HQs were up to an order-of-magnitude greater than 1.0 and PAH HQs were up to two orders-of-magnitude greater than 1.0, with both COCs exceeding a HQ of 1.0 over the full concentration and toxicity range evaluated (Table 8-5). The third line of evidence, field observations, was inconclusive.

8.9.9 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Benthivorous Waterfowl Populations

Sustainability of local waterfowl populations was assessed using three lines of evidence. The first was modeling dietary doses of chemicals. The second was to compare measured water column concentrations to water quality criteria for the protection of wildlife. The third line of evidence was field-based observation. The first two lines of evidence suggested that waterfowl have been adversely affected to some degree by chemicals found in Onondaga Lake via exposure to contaminated water and food sources. Mercury HQs were up to an order-of-magnitude greater than 1.0 and PAH HQs were up to two orders-of-magnitude greater than 1.0, with both COCs exceeding a HQ of 1.0 over the full concentration and toxicity range evaluated (Table 8-5). The third line of evidence, field observations, was inconclusive.

8.9.10 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Piscivorous Bird Populations

Sustainability of local piscivorous bird populations was assessed using three lines of evidence. The first was modeling dietary doses of chemicals. The second was to compare measured water column concentrations to water quality criteria for the protection of wildlife. The third line of evidence was field-based observation. The first two lines of evidence suggested that piscivorous birds have been adversely affected to some degree by chemicals found in Onondaga Lake, and by mercury in particular. Mercury HQs were greater than 1.0 for the full point estimate range of risk for all three piscivorous receptor species and were over an order-of-magnitude greater than the NOAELs (Table 8-5). The third line of evidence, field observations, was inconclusive.

8.9.11 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Carnivorous Bird Populations

Sustainability of local carnivorous bird populations was assessed using two lines of evidence. The first was modeling dietary doses of chemicals and the second was field-based observation. Modeled dietary doses suggested that carnivorous birds have been adversely affected to some degree by chemicals found in Onondaga Lake, and by total PAHs in particular, for which HQs were greater than 1.0 for the full point estimate range of risk (Table 8-5). The second line of evidence, field observations, was inconclusive.

8.9.12 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Insectivorous (Aquatic and Terrestrial Insect Phases) Mammal Populations

Sustainability of local insectivorous mammal populations was assessed using three lines of evidence. The first was modeling dietary doses of chemicals. The second was to compare measured water column concentrations to water quality criteria for the protection of wildlife. The third line of evidence was field-based observation. The first two lines of evidence suggested that insectivorous mammals feeding on aquatic invertebrates have been adversely affected to some degree by chemicals found in Onondaga Lake. Methylmercury and PAHs had the highest HQs, with HQs greater than 1.0 for the full point estimate range of risk and values up to an order-of-magnitude above 1.0 (Table 8-6).

Insectivorous mammals feeding on terrestrial invertebrates in the four wetlands around Onondaga Lake may also be adversely affected by chemicals found in Onondaga Lake. Risk varied by wetland area, with Wetland SYW-19, located near the mouth of Harbor Brook, having the greatest number of COCs with HQs above 1.0 (Table 8-7). In the wetland areas, risks from exposure to methylmercury for the full point estimate range of risk in all four wetlands were up to two orders-of-magnitude above 1.0. Risks from exposure to total PAHs, hexachlorobenzene, and dioxins/furans were up to three orders-of-magnitude above 1.0. Risks to insectivorous mammals in the dredge spoils soils were primarily due to exposure to hexachlorobenzene. The third line of evidence, field observations, was inconclusive.

8.9.13 Sustainability (i.e., Survival, Growth, and Reproduction) of Local Piscivorous Mammal Populations

The sustainability of local piscivorous mammal populations was assessed using three lines of evidence. The first was modeling dietary doses of chemicals. The second was to compare measured water column concentrations to water quality criteria for the protection of wildlife. The third line of evidence was field-based observation. The first two lines of evidence suggested that piscivorous mammals feeding around Onondaga Lake have been adversely affected to some degree by chemicals found in the lake, and in particular by mercury and total PCBs (Table 8-6). The third line of evidence, field observations, was inconclusive.

8.10 Uncertainties

To integrate the various components of the BERA, the results of the risk characterization and associated uncertainties were evaluated to assess the risk of adverse effects to Onondaga Lake receptors as a result of exposure to chemicals and stressors originating in the lake. Uncertainty exists because of data limitations (e.g., extrapolating between species for TRVs) and natural variability (e.g., fish tissue concentrations, ingestion rates). Uncertainty is an inherent component of risk assessments. Elements of uncertainty in the BERA were identified and efforts were made to minimize them. For components in which a moderate degree of uncertainty was unavoidable (e.g., sampling data), efforts were made to minimize any systematic bias associated with the data. The Onondaga Lake BERA uses various point estimates of exposure and response to develop a range of point estimates of risk (i.e., 95 percent UCL, mean, NOAEL, and LOAEL) to aid in judging the ecological significance of risks.

In addition to the uncertainties that are common to many risk assessments, there were several uncertainties associated with the BERA that are specific to Onondaga Lake. Uncertainties associated with factors limiting the distribution and abundance of macrophytes, the effects of calcium and oncolites on the aquatic community, the effects on the Onondaga Lake ecosystem if conditions allow the return of an oxic hypolimnion, and the effects of eutrophication on the lake ecosystem were examined and discussed in the BERA.

8.11 Conclusions

Multiple lines of evidence were used to evaluate major components of the Onondaga Lake ecosystem to determine if lake contamination has adversely affected plants and animals around Onondaga Lake. Almost all lines of evidence indicate that the Honeywell-related contaminants and ionic waste in Onondaga Lake have produced adverse ecological effects at all trophic levels examined.

The aquatic macrophytes in the lake have been adversely affected by lake conditions, and the resulting loss of macrophyte habitat that formerly provided valuable feeding and nursery areas has undoubtedly affected the aquatic invertebrates and vertebrates living in Onondaga Lake. In addition to general habitat loss, there has been bioaccumulation of mercury and possibly other chemicals in most organisms serving as a food source in the lake, including phytoplankton, zooplankton, benthic invertebrates, and fish. Exceedances of site-specific sediment PECs suggest adverse effects to benthic invertebrates will frequently occur (Ingersoll et al., 2000) in most areas of the lake. The greatest number and magnitude of exceedances were found in areas in the southern portion of the lake and near Ninemile Creek (Figure 8-2).

Summary of Findings of the BERA

Comparisons of measured tissue concentrations and modeled doses of chemicals to TRVs show exceedances of HQs for site-related chemicals throughout the range of the point estimates of risk. Many of the contaminants in the lake are persistent and, therefore, the risks associated with these contaminants are unlikely to decrease significantly in the absence of remediation. On the basis of these comparisons, it has been determined through the BERA that all receptors of concern are at risk. Contaminants and stressors in the lake have either impacted or potentially impacted every trophic level and feeding preference examined in the BERA.

Based on sediment toxicity testing, the most toxic sediments are found in the nearshore zone in the southern part of the lake between Tributary 5A and Ley Creek. These sediment locations have the highest number of compounds that exceed the site-specific sediment effect concentrations. The contaminants presenting the greatest risk from chemical toxicity are mercury, chlorinated benzenes, PAHs, PCBs, and PCDD/PCDFs.